Dynamic Eco-Lanes Version 1.0

Other Vehicles

Driver

Connected Vehicle Roadway Equipment

Other Centers
(*Traffic Management Centers, Emissions Management Centers, ISPs, Enforcement Agencies, etc.*)

Vehicle

Other Onboard Sensors

Vehicle Diagnostics Systems

Vehicle Actuators

In-Vehicle System

Cell Tower

DYNAMIC MESSAGE SIGN (DMS)

ITS Roadway Equipment

Back Office

Dynamic Eco-Lane System

Vulnerable Road User

Smart Grid

Inductive Charging Roadway Equipment

Satellite

Operator

Home or Office

LEGEND
- energy transfer
- wired or wireless communications
- wireless communications

Dynamic Eco-Lanes Transformative Concept

The Dynamic Eco-Lanes Transformative Concept features dedicated lanes – similar to high-occupancy vehicle (HOV) or high-occupancy toll (HOT) lanes – optimized for the environment. Applications comprising the Eco-Lanes Transformative Concept include eco-speed harmonization, eco-cooperative adaptive cruise control, and eco-ramp metering. At the heart of this Transformative Concept is an administrative application that supports the operation of Dynamic Eco-Lanes, including establishing parameters for entering the lanes and defining or geo-fencing the Eco-Lanes boundaries. Dynamic eco-lanes would use operational strategies implemented by the operating entity (e.g., Traffic Management Center) to reduce vehicle emissions in the lanes.

- **Dynamic Eco-Lanes |** Dynamic eco-lanes are similar to current HOV lanes. They are optimized for the environment and encourage use by low-emission, high-occupancy, freight, transit, and alternative-fuel or regular vehicles operating in eco-friendly ways (i.e., eco-speed limits, vehicle platooning). The Dynamic Eco-Lanes application establishes parameters and defines or geo-fences the eco-lanes boundaries. Eco-lanes parameters may include the types of vehicles allowed in the eco-lanes, emissions parameters for entering the eco-lanes, the number of lanes, and the start and end of the eco-lanes. The application also conveys pre-trip and en route traveler information about dynamic eco-lanes to travelers, including information about parameters for vehicles to enter the eco-lanes, current and predicted traffic conditions in the eco-lanes, and geographic boundaries of the eco-lanes.

- **Eco-Speed Harmonization |** The Eco-Speed Harmonization application determines eco-speed limits based on traffic conditions, weather information, and GHG and criteria pollutant information. The purpose of speed harmonization is to dynamically change speed limits on links that approach areas of traffic congestion, bottlenecks, incidents, special events, and other conditions that affect flow. Speed harmonization assists in maintaining flow, reducing unnecessary stops and starts, and maintaining consistent speeds, thus reducing fuel consumption, GHG emissions, and other emissions on the roadway. Eco-speed limits can be broadcast by roadside equipment (RSE) units and received by on-board equipment (OBE) units or displayed on VSL signs located along the roadway. This application is similar to current VSL applications, although the speed recommendations seek to minimize emissions and fuel consumption along the roadway.

- **Eco-Cooperative Adaptive Cruise Control |** The Eco-Cooperative Adaptive Cruise Control application automatically controls the speed of a vehicle using V2V communications to transmit a vehicle's instantaneous speed to following vehicles. This application allows following vehicles to use ACC aimed at relieving a driver from manually adjusting his or her speed to maintain a constant speed and a safe time gap from the lead vehicle. The Eco-Cooperative Adaptive Cruise Control application incorporates other information, such as road grade, roadway geometry, and road weather information, to determine the most environmentally efficient trajectory for the following vehicle. In the long

term, the application may also consider vehicle platoons, where two or more vehicles travel with small gaps, reducing aerodynamic drag. Platooning relies on V2V communication that allows vehicles to accelerate or brake with minimal lag to maintain the platoon with the lead vehicle. The reduction in drag results in reduced fuel consumption, greater fuel efficiency, and less pollution for vehicles. This application is applicable to all vehicle classes.

- **Eco-Ramp Metering |** The Eco-Ramp Metering application determines the most environmentally efficient operation of traffic signals at freeway on-ramps to manage the rate of entering vehicles. This application collects traffic and environmental data to allow on-ramp merge operations that minimize overall emissions, including traffic and environmental conditions on the ramp and on the freeway upstream and downstream of the ramp. Using this information, the application determines a timing plan for the ramp meter based on current and predicted traffic and environmental conditions. The objective for this application is to produce timing plans that reduce overall emissions, including reducing emissions from bottlenecks forming on the freeway as well as emissions from vehicles on the ramp.

- **Connected Eco-Driving |** The Connected Eco-Driving application provides customized real-time driving advice to drivers, allowing them to adjust behaviors to save fuel and reduce emissions. This advice includes recommended driving speeds, optimal acceleration and deceleration profiles based on prevailing traffic conditions, and more local interactions with nearby vehicles. Finally, the application may also consider vehicle-assisted strategies, where the vehicle automatically implements the eco-driving strategy (i.e., change gears, switch power sources, or use start-stop capabilities to turn off the vehicle's engine while it is sitting in congestion).

- **Multi-Modal Traveler Information |** The Multi-Modal Traveler Information application provides pre-trip and en route multimodal traveler information to encourage transportation choices with reduced environmental impacts. The application collects traffic and environmental data from connected vehicles and other sources and uses it to determine real-time or predicted traffic conditions. This information is provided to travelers so they can either plan to or dynamically adjust departure times or mode choices or select an alternate route. Traffic conditions include information about roadway speeds and travel times as well as predicted traffic conditions. Travelers can use this information to adjust their departure time or select an alternate route. Another key component of this application is providing travelers with transit options to encourage mode shift, including information about transit schedules and real-time transit vehicle arrival and departure times.

Breakout Session Questions

1. Does the Data Flow Diagram accurately depict the Transformative Concept?

2. Do you agree with the data being exchanged between the actors?

3. Is there any data identified in the read-ahead package that is unlikely to be exchanged between actors?

4. Is there any data that should be exchanged between actors that is not identified in the read-ahead package?

5. Based on what you heard about the Dynamic Eco-Lanes Transformative Concept, what aspect stands out? What is useful to you as a deployer or operator? Are there components of this Transformative Concept that you would consider implementing in the next 5 years? 10 years? 20 years?

6. The Dynamic Eco-Lanes Transformative Concept encourages travelers to opt-in to environmentally friendly applications (e.g., CACC and eco-driving applications). What would incentivize travelers to opt-in to these "eco" applications and/or decide to use the eco-lanes?

7. What aspects of the AERIS Transformative Concepts and applications do you think could apply to transit and/or freight operations?

8. To date, much of the discussion about eco-lanes has focused on freeway operations. Do you think the concept of eco-lanes could be applied to arterials? If so, what would Dynamic Eco-Lanes look like on an arterial? What similarities/differences would there be between arterial and freeway eco-lanes?

Table 1. Dynamic Eco-Lanes Data Flows and Actions

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
1	**In-Vehicle System and Driver**	In-Vehicle System sends to Driver • Eco-Lanes Parameter Information (e.g., Location, entrance criteria, Eco-Speed Limits, etc.) • Vehicle Platooning Parameters (e.g., locations, number of vehicles, speeds, etc.) • Eco-Driving Information • Traffic conditions • Environmental conditions (e.g., code red air quality alerts) • Road weather conditions • Status of an electric vehicle's electric charge and charge received from inductive charging field infrastructure Driver Sends to In-Vehicle System • Activation of Application (e.g., activate eco-Cooperative adaptive cruise control) • Updates to configurable parameters	• IVS-DC-01: Collected Driver Input • IVS-D-03: Provide Traffic Conditions to the Driver • IVS-D-04: Provide Environmental Conditions to the Driver • IVS-D-05: Provide Eco-Lanes Parameters to the Driver • IVS-D-06: Provide Vehicle Platooning Parameters to the Driver • IVS-D-07: Provide Eco-Driving Information to the Driver • IVS-DI-01: Provide Driver Interface
2	**In-Vehicle System and Other Vehicles**	In-Vehicle System sends to Other Vehicles • Vehicle status data (e.g., BSM data including vehicle's location, heading, speed, acceleration, braking status, size, etc.) Other Vehicles send to In-Vehicle System • Vehicle status data (e.g., BSM data including vehicle's location, heading, speed, acceleration, braking status, size, etc.)	• IVS-DC-08: Receive Vehicle Status Data from Other Vehicles • IVS-D-01: Disseminate Vehicle Status Information
3	**In-Vehicle System and Connected Vehicle Roadway**	In-Vehicle System sends to Connected Vehicle Roadway Equipment, Cell Tower, and Satellite • Vehicle status data (e.g., BSM data including vehicle's location, heading, speed, acceleration, braking status, size, etc.) • Vehicle status environmental data (e.g., BEM data including the	• IVS-DC-02: Receive Traffic Conditions • IVS-DC-03: Collected Geographic Information Description Data • IVS-DC-04: Receive Environmental

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
	Equipment **In-Vehicle System and Cell Tower** **In-Vehicle System and Satellite**	vehicle's fuel type, engine type, current emissions, average emissions, current fuel consumption, and average fuel consumption) <u>Connected Vehicle Roadway Equipment, Cell Tower, and Satellite sends to the In-Vehicle System</u> • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Environmental conditions (e.g., air quality information, code red air quality alerts) • Road weather conditions (e.g., pavement conditions) • Eco-Lanes Parameter Information (e.g., Location, entrance criteria, etc.) • Eco-Speed Limits • Vehicle Platooning Parameters (e.g., locations, number of vehicles, speeds, etc.) • Geographic Information Description Data (e.g., lane geometries, lane configurations, posted speed limits, etc.) • Notice of Violation	Conditions • IVS-DC-05: Receive Vehicle Platooning Parameters • IVS-DC-06: Receive Eco-Lanes Parameter Information • IVS-DC-07: Receive Eco-Speed Limits • IVS-D-01: Disseminate Vehicle Status Data • IVS-D-02: Disseminate Vehicle Status Environmental Data
4	**Cell Tower and Vulnerable Road User**	<u>Vulnerable Road User receives from Cell Tower:</u> • Eco-Lanes Parameter Information (e.g., Location, entrance criteria, etc.) • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Environmental conditions (e.g., air quality information, code red air quality alerts)	• DELS-D-02: Disseminate Traffic Conditions to Other Centers and Travelers • DELS-D-04: Disseminate Environmental Conditions to Other Centers and Travelers • DELS-D-09: Disseminate Eco-Lanes Parameters to Other Centers and Travelers
5	**Connected Vehicle Roadway Equipment and**	<u>Connected Vehicle Roadway Equipment, Cell Tower, and Satellite sends to Dynamic Eco-Lane System</u> • Vehicle status data (vehicle's location, heading, speed,	• DELS -DC-01: Collect Traffic Data • DELS -DC-02: Collected Environmental Data

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
	Dynamic Eco-Lane System **Cell Tower and Dynamic Eco-Lane System** **Satellite and Dynamic Eco-Lane System**	acceleration, braking status, size, etc.) • Vehicle status environmental data (e.g., BEM data including the vehicle's fuel type, engine type, current emissions, average emissions, current fuel consumption, and average fuel consumption) <u>Dynamic Eco-Lane System sends to Connected Vehicle Roadway Equipment, Cell Tower, and Satellite</u> • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Environmental conditions (e.g., air quality information, code red air quality alerts) • Road weather conditions (e.g., pavement conditions) • Eco-Lanes Parameter Information (e.g., Location, entrance criteria, etc.) • Eco-Speed Limits • Vehicle Platooning Parameters (e.g., locations, number of vehicles, speeds, etc.) • Notice of Violations	• DELS -D-03: Disseminate Traffic Conditions for the Eco-Lanes to Vehicles • DELS -D-05: Disseminate Environmental Conditions to Vehicles • DELS -D-06: Disseminate Eco-Speed Limits to Vehicles • DELS -D-07: Disseminate Vehicle Platooning Parameters • DELS -D-08: Disseminate Eco-Lanes Parameters • DELS -D-09: Provide Notice of Violation to Vehicles
6	**ITS Roadway Equipment and Dynamic Eco-Lane System**	<u>ITS Roadway Equipment sends to Dynamic Eco-Lane System</u> • Traffic data (e.g., speed, volume, occupancy, pedestrian calls, etc.) • Environmental data (e.g., air quality data, etc.) • Road weather data (e.g., road friction, precipitation, temperature, etc.) • Field Device operational status • Potential Vehicle Violations <u>Dynamic Eco-Lane System sends to ITS Roadway Equipment</u> • Geographic Information Description Data (e.g., lane geometries, lane configurations, posted speed limits, etc.) • Eco-Speed Limits	• DELS -DC-01: Collect Traffic Data • DELS -DC-02: Collected Environmental Data • DELS -D-06: Disseminate Eco-Speed Limits to Vehicles • DELS -D-07: Disseminate Vehicle Platooning Parameters • DELS -D-08: Disseminate Eco-Lanes Parameters • DELS –DP-09: Detect Violations for

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
		• Eco-Lanes Parameter Information (e.g., Location, entrance criteria, etc.) • Vehicle Platooning Parameters (e.g., locations, number of vehicles, speeds, etc.) • Ramp Meter Timing Plans	Individual Vehicles • DELS-D-01: Provide Ramp Meter Timing Plans to Roadway Equipment
7	**Dynamic Eco-Lane System and Other Centers**	Dynamic Eco-Lane System sends to other Traffic Management Centers: • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Environmental conditions (e.g., air quality data, code red air quality alerts) • Ramp Meter timing plans in operation • Eco-Lanes and Vehicle Platooning Parameters • Road weather data (e.g., road conditions) Dynamic Eco-Lane System sends to Emissions Management Centers: • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Environmental conditions (e.g., air quality data, code red air quality alerts) • Road weather data (e.g., road conditions) Dynamic Eco-Lane System sends to ISPs: • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Environmental conditions (e.g., air quality data, code red air quality alerts) • Eco-Lanes and Vehicle Platooning Parameters • Road weather data (e.g., road conditions) Dynamic Eco-Lane System sends to Enforcement Agencies: • Notice of Violation • Eco-Lanes and Vehicle Platooning Parameters	• DELS-DC-01: Collect Traffic Data • DELS -DC-02: Collect Environmental Data • DELS -D-02: Disseminate Traffic Information to Other Centers and ISPs • DELS -D-04: Disseminate Environmental Conditions to Other Centers • DELS-D-11: Notify Enforcement Agencies of Violations

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
		Other Centers sends to Dynamic Eco-Lane System: • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Ramp meter timing plans in operations • Eco-Lanes and Vehicle Platooning Parameters in operation • Environmental conditions (e.g., air quality data, code red air quality alerts) • Road weather data (e.g., road conditions)	
8	**Dynamic Eco-Lane System and Home or Office**	Dynamic Eco-Lane System sends to Homes or Offices: • Eco-Lanes Parameter Information (e.g., Location, entrance criteria, etc.) • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Environmental conditions (e.g., air quality information, code red air quality alerts)	• DELS-D-02: Disseminate Traffic Conditions to Other Centers and Travelers • DELS-D-04: Disseminate Environmental Conditions to Other Centers and Travelers • DELS-D-09: Disseminate Eco-Lanes Parameters to Other Centers and Travelers
9	**Dynamic Eco-Lane System and Operator**	Dynamic Eco-Lane System sends to Operator • Traffic conditions • Environmental conditions • Road weather conditions • Performance measures • Eco-Lanes System operational status • Archive data Operator sends to Dynamic Eco-Lane System • Operator inputs (e.g., create eco-lane parameters, implement new platooning plan, or add new equipment (e.g., new ramp meters) to the system)	• DELS-DC-05: Collect Operator Input • DELS -UI-01: User Interface

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
10	**Inductive Charging Roadway Equipment and Vehicle**	Inductive Charging Roadway Equipment sends to Vehicle • Request for charge • Inductive charge • Request for payment Vehicle sends to Inductive Charging Roadway Equipment • Approval to receive inductive charge • Payment information • Provide energy back into the Smart Grid	• IVS-DC-10: Receive Inductive Charge
11	**In-Vehicle System**	• Collect Data o Driver Input (e.g., activation of application, system parameters, etc.) o Traffic conditions (e.g., current and predicted traffic speeds, travel times, incidents, queues, etc.) o Environmental conditions (air quality information, code red day alert, etc.) o Road weather conditions (e.g., pavement conditions) o Geographic Information Description data (e.g., lane geometries, lane configurations, posted speed limits, etc.) o Eco-Lanes Parameter Information (e.g., Location, entrance criteria, etc.) o Eco-Speed Limits o Vehicle Platooning Parameters (e.g., locations, number of vehicles, speeds, etc.) o Vehicle diagnostics data (e.g., engine, emissions, GPS, and onboard sensor data) o Vehicle status data from nearby vehicles (e.g., BSM data including vehicle's location, heading, speed, acceleration, braking status, size, etc.) o Inductive charge • Process Data o Determine eco-driving recommendations (e.g., recommended speeds)	• IVS-DC-01: Collect Driver Input • IVS-DC-02: Receive Traffic Conditions Data • IVS-DC-03: Collect Geographic Information Descriptions (GID) Data • IVS-DC-04: Receive Environmental Conditions Data • IVS-DC-05: Receive Vehicle Platooning Parameters • IVS-DC-06: Receive Eco-Lanes Parameter Information • IVS-DC-07: Receive Eco-Speed Limits • IVS-DC-08: Receive Vehicle Status Data from Other Vehicles (i.e., BSM) • IVS-DC-09: Collect Vehicle Diagnostics Data • IVS-DC-10: Receive Inductive Charge • IVS-DP-01: Generate Eco-Driving Strategies

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
		- Determine if Vehicle meets Eco-Lane Parameters and / or Platooning Parameters - Determine Eco-CACC and Platooning Strategies - Determine vehicle emissions data (e.g., determine BEM for disseminate) **Disseminate Data** - Eco-driving recommendations to driver and driver feedback - Traffic and Environmental Conditions to the driver - Eco-Lanes and Vehicle Platooning Parameters to the driver - Vehicle status data (e.g., BSM data including vehicle's location, heading, speed, acceleration, braking status, size, etc.) - Vehicle status environmental data (e.g., BEM data including the vehicle's fuel type, engine type, current emissions, average emissions, current fuel consumption, and average fuel consumption) **Vehicle Control** - Vehicle assisted control (e.g., control of vehicle acceleration and speed) **Driver Interface** - Activation of Application (e.g., activate eco-driving application) - Updates to configurable parameters - Eco-driving recommendations (e.g., recommended driving speeds, driver feedback, etc.) - Traffic conditions - Environmental conditions (e.g., code red air quality alerts) - Road weather conditions - Status of an electric vehicle's electric charge and charge received from inductive charging field infrastructure	- IVS-DP-02: Determine if Vehicle Meets Criteria for Vehicle Platooning - IVS-DP-03: Generate Eco- Cooperative Adaptive Cruise Control and Vehicle Platooning Strategies - IVS-DP-04: Determine if the Vehicle Meets Criteria to Enter the Dynamic Eco-Lanes - IVS-DP-05: Process Traffic and Environmental Data for Traveler Information Messages - IVS-DP-06: Determine Vehicle Emissions Data - IVS-D-01: Disseminate Vehicle Status Data - IVS-D-02: Disseminate Vehicle Status Environmental Data - IVS-D-03: Provide Traffic Conditions to the Driver - IVS-D-04: Provide Environmental Conditions to the Driver - IVS-D-05: Provide Eco-Lanes Parameters to the Driver - IVS-D-06: Provide Vehicle Platooning Parameters to the Driver - IVS-D-07: Provide Eco-Driving Information to the Driver - IVS-VC-01: Provide Eco-Driving Vehicle Assisted Control Strategy

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
			• IVS-DI-01: Provide Operator Interface

12	**Dynamic Eco-Lane System**	• Collect Data
		  o Traffic data (e.g., speeds, volumes, occupancy, vehicle types, turning movements, CCTV images, incidents, etc.)
		  o Environmental data (e.g., vehicle emissions, local air conditions, etc.)
		  o Road weather conditions road friction, precipitation, temperature, etc.)
		  o Operational status of dynamic eco-lane system and other devices
		  o Operator input (i.e., new device installation, new timing plans, eco-lanes parameters, etc.)
		
		• Process Data
		  o Process traffic data
		  o Generate predicted traffic conditions
		  o Process environmental data
		  o Generate predicted environmental data
		  o Generate Eco-Speed Limits
		  o Generate Vehicle Platooning Parameters
		  o Create and Decommission Eco-Lanes
		  o Detect Violations
		  o Generate ramp meter timing strategy (e.g., determine eco-timing strategy)
		
		• Disseminate Data
		  o Ramp Meter timing plans
		  o Traffic conditions (e.g., current and predicted traffic speeds, travel times, volumes, incidents, queues, etc.)
		  o Environmental conditions (e.g., air quality, vehicle emissions at intersection level, corridor level, etc.)
		  o Road weather conditions (e.g., pavement conditions)
		  o Eco-Speed Limits
		  o Vehicle Platooning Parameters
		  o Eco-Lanes Parameters
			• DELS-DC-01: Collect Traffic Data
			
			• DELS-DC-02: Collect Environmental Data
			
			• DELS-DC-03: Collect Field Device Status Data
			
			• DELS-DC-04: Collect Vehicle Specific Data
			
			• DELS-DC-05: Collect Operator Input
			
			• DELS-DP-01: Process Traffic Data
			
			• DELS-DP-02: Generate Predicted Traffic Conditions and Forecast Demand
			
			• DELS-DP-03: Process Environmental Data
			
			• DELS-DP-04: Generate Predicted Emissions Profile
			
			• DELS-DP-05: Generate Ramp Meter Timing Strategy
			
			• DELS-DP-06: Generate Eco-Speed Limits
			
			• DELS-DP-07: Generate Vehicle Platooning Parameters
			
			• DELS-DP-08: Create and Decommission Dynamic Eco-Lanes
			
			• DELS-DP-09: Detect Violations for Individual Vehicles
			
			• DELS-D-01: Provide Ramp Meter Timing Plans to Roadway Equipment

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS

		o Notice of Violation
		
		• User Interface
		   o Traffic conditions
		   o Environmental conditions
		   o Road weather conditions
		   o Performance measures
		   o Dynamic eco-lanes system operational status
		   o Archive data
		   o Operator inputs (e.g., creating new ramp meter timing plans, implementing timing plans, creating eco-lane parameters or adding new equipment to the system)
			• DELS-D-02: Disseminate Traffic Conditions to Other Centers and Travelers
			
			• DELS-D-03: Disseminate Traffic Conditions for the Eco-Lanes and Regular Lanes to Vehicles
			
			• DELS-D-04: Disseminate Environmental Conditions to Other Centers and Travelers
			
			• DELS-D-05: Disseminate Environmental Conditions to Vehicles
			
			• DELS-D-06: Disseminate Eco-Speed Limits to Vehicles
			
			• DELS-D-07: Disseminate Vehicle Platooning Parameters
			
			• DELS-D-08: Disseminate Eco-Lanes Parameters to Vehicles
			
			• DELS-D-09: Disseminate Eco-Lanes Parameters to Other Centers and Travelers
			
			• DELS-D-10: Provide Notice of Violation to Vehicles
			
			• DELS-D-11: Notify Enforcement Agencies of Violations
			
			• DELS-DA-01: Archive Data
			
			• DELS-DA-02: Determine Performance Measures
			
			• DELS-UI-01: User Interface

Actor and System Definitions

- **Connected Vehicle Roadway Equipment (includes RSE, cell tower, and Satellite) |** The Connected Vehicle Roadway Equipment actor includes the RSE units distributed on and along the roadway. These devices are capable of both transmitting and receiving data using DSRC radios, using the 5.9 GHz band approved for DSRC use by the FCC. The devices may also support other wireless communications, such as cellular and Wi-Fi communications. RSE units support the appropriate IEEE and SAE standards (IEEE 802.11p, IEEE 1609 family, and SAE J2735). The Connected Vehicle Roadway Equipment Actor also includes local processing capabilities to support processing of data at the roadside.

- **Driver |** The Driver actor represents the human entity that operates a licensed vehicle on the roadway. Included are operators of private, transit, and commercial vehicles where the data being sent or received is not particular to the type of vehicle. Thus, this actor originates driver requests and receives driver information that reflects the interactions which might be useful to all drivers, regardless of vehicle classification.

- **Dynamic Eco-Lanes System |** The Dynamic Eco-Lanes System is a computerized transportation operations system that employs communication technology to gather traffic and environmental information from multiple sources including ITS Roadway Equipment, Connected Vehicle Roadway Equipment, and other systems. The system then processes these data and determines whether an eco-lane should be created or decommissioned along a roadway. The Dynamic Eco-Lanes System is also responsible for managing operational strategies (e.g., eco-speed limits and vehicle platooning) in the eco-lanes with the objective of reducing fuel consumption and overall emissions along the roadway segment. Data considered in the creation or decommissioning of an eco-lane includes real-time and predicted traffic and environmental conditions, location and duration of special events, or other data.

- **Emissions Management Center (Other Centers) |** The Emissions Management Center actor provides the capabilities for air quality managers to monitor and manage air quality. These capabilities include collecting emissions data from distributed emissions sensors within the Roadway actor and from Vehicle actors, and ingesting regional air quality data from external sources and sensors such as operated by the National Weather Service (NWS) or the EPA. These sensors monitor general air quality for an area and also monitor the emissions of individual vehicles on the roadway. The sector emissions measures are collected, processed, and used to identify sectors exceeding or predicted to exceed pre-defined pollution levels. This information is provided to Traffic Management actors to implement strategies intended to reduce emissions in and around the problem areas. This actor provides any functions necessary to inform the violators and

otherwise ensure timely compliance with emissions standards. This actor may co-reside with the Traffic Management actor or may operate in its own distinct location depending on regional preferences and priorities.

- **Enforcement Agencies |** The Enforcement Agencies actor represents the systems that receive reports of violations detected by various ITS facilities including individual vehicle emissions, toll violations, excessive speed in work zones, etc.

- **Inductive Charging Roadway Equipment |** The inductive Charging Roadway Equipment actor includes roadside infrastructure deployed along the roadway that uses magnetic fields to wirelessly transmit large electric currents between metal coils placed several feet apart. This infrastructure enables inductive charging of electric vehicles including cars, trucks, and buses. Roadside Charging Infrastructure supports static charging capable of transferring electric power to a vehicle parked in a garage or on the street and vehicles stopped at a traffic light. It also supports charging vehicles moving at highway speeds.

- **Information Service Provider |** The Information Service Provider actor collects, processes, stores, and disseminates transportation information to system operators and the traveling public. The actor can play several different roles in an integrated ITS. In one role, the ISP provides a data collection, fusing, and repackaging function, collecting information from transportation system operators and redistributing this information to other system operators in the region and other ISPs. In this information redistribution role, the ISP provides a bridge between the various transportation systems that produce the information and the other ISPs and their subscribers that use the information. The second role of an Information Service Provider is focused on delivery of traveler information to subscribers and the public at large. Information provided includes basic advisories, traffic and road conditions, transit schedule information, yellow pages information, ride-matching information, and parking information. The subsystem also provides the capability to provide specific directions to travelers by receiving origin and destination requests from travelers, generating route plans, and returning the calculated plans to the users. In addition to general route planning for travelers, the Information Service Provider also supports specialized route planning for vehicle fleets. In this third role, the ISP function may be dedicated to, or even embedded within, the dispatch system. Reservation services are also provided in advanced implementations. Both basic one-way (broadcast) and personalized two-way information provision are supported. The ISP is most commonly implemented as an Internet web site, but it represents any traveler information distribution service including systems that broadcast digital transportation data (e.g., satellite radio networks) and systems that support distribution through I2V communications networks. The ISP accomplishes these roles using constantly evolving technologies like the Internet (World Wide Web pages), direct broadcast communications (email alerts, pagers, satellite radio network data broadcasts), communications through I2V communications networks, etc.

- **ITS Roadway Equipment |** The ITS Roadway Equipment actor includes the equipment distributed on and along the roadway that monitors and controls traffic and monitors and manages the roadway itself. Equipment includes traffic detectors, environmental sensors, traffic signals, highway advisory radios (HAR), DMSs, CCTV cameras, and video image processing systems, grade crossing warning systems, and freeway ramp metering systems. HOV lane management, reversible lane management functions, and barrier systems that control access to transportation infrastructure such as roadways, bridges, and tunnels are also supported. This actor also provides the capability for environmental monitoring including sensors that measure road conditions, surface weather, and vehicle emissions. In adverse conditions, automated systems can be used to apply anti-icing materials, disperse fog, etc.

- **In-Vehicle System |** The In-Vehicle System resides in the vehicle and is used to collect, process, and disseminate data to various actors including the driver of the vehicle. A major function of the In-Vehicle System is to collect information about the dynamic eco-lanes, as well as traffic and environmental conditions, and present this information to the driver to assist him or her in making informed pre-trip and en-route travel choices. This information may include the location of the dynamic eco-lanes, start and end time for the eco-lanes, criteria for entering the eco-lanes, eco-speed limits while traveling in the eco-lanes, and parameters for vehicle platooning. Additionally, the In-Vehicle System may present drivers with information about traffic conditions and environmental conditions in both the eco-lanes and adjacent regular lanes. This information may include real-time travel times, incident information, or estimated fuel consumption for both the eco-lanes and regular lanes. This information would be provided to the driver allowing him/her to make informed decisions about using the eco-lanes.

- **Operator |** The Operator actor represents the human entity that directly interfaces with the Dynamic Eco-Lanes System.

- **Other On-Board Sensors |** The Other On-board Sensors Actor represents sensors that may be installed on vehicles to collect traffic or environmental conditions data. For example, sensors may be equipped on a vehicle to measure atmospheric, surface (i.e., pavement and soil), and/or hydrologic conditions.

- **Vehicle |** The Vehicle actor provides the sensory, processing, storage, and communications functions necessary to support efficient, safe, and environmentally efficient travel. Both one-way and two-way communications options, including 5.9 GHz band approved for DSRC use by the FCC and other wireless communications such as cellular, support a spectrum of information services. This capability allows the vehicle actor to disseminate information about its status (i.e., current speed, acceleration, braking, and average emissions) to other vehicles or to the Connected Vehicle Roadway actor. Advanced sensors, processors, enhanced driver interfaces, and actuators in the Vehicle actor complement the driver information services so that, in addition to making informed mode and route selections, the driver travels these

routes in a safer and more consistent manner. This Actor may also include more advanced functions that assume limited control of the vehicle to maintain safe headway.

- **Traffic Management Center (Other Centers)** | The Traffic Management Center actor monitors and controls traffic and the road network. It represents the functionality provided by centers that manage a broad range of transportation facilities including freeway systems, rural and suburban highway systems, and urban and suburban traffic control systems. This actor communicates with the Roadway actor to monitor and manage traffic flow and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status (e.g., ramp meters). This actor also manages traffic and transportation resources to support allied agencies in responding to, and recovering from, incidents ranging from minor traffic incidents through major disasters. The Traffic Management actor supports HOV lane management and coordination, road pricing, and other demand management policies that can alleviate congestion and influence mode selection. The actor communicates with other Traffic Management actors to coordinate traffic information and control strategies in neighboring jurisdictions.

- **Vehicle Diagnostic System** | The Vehicle Diagnostic Systems actor represents computer-based systems, located on vehicles, designed to monitor the performance of some of an engine's major components including those responsible for controlling emissions.

- **Vehicle Actuators** | The Vehicle Actuator actor represents an electromechanical device such as a relay, solenoid, or motor. Within the vehicle, computers use sensor data to control different systems on the vehicle through the use of actuators. Actuators can adjust engine idle speed, change suspension height, regulate the fuel metered into the system, accelerate or decelerate the vehicle, or implement the braking system.

- **Vulnerable Road User** | Non-motorized road users, such as pedestrians and cyclists as well as motor-cyclists and persons with disabilities or reduced mobility and orientation Vulnerable road users